Final exam, General Physics I (english), January 15, 2016

Nom, Prénom:
SciPer:

Instructions

1. Write clearly and in ink (pen), and indicate clearly your result (with your reasoning explained).
2. Only responses written on the A4 sheets of the exam (front and back) will be taken into account.
3. Justify your calculations and responses by describing the laws of physics you have used.

Allowed:

- one page A4 (front and back) *handwritten*

Not allowed:

- Any form of electronic device including a calculator
- Leaving the room without authorization

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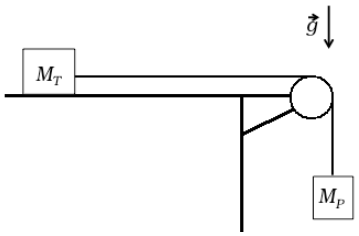
1. Escape through a window

The building is on fire, so you and your flatmate (colocataire) attach one end of a rope to a table (whose mass is M_T), and throw the other end out of the window to escape. Coefficients of static and kinetic friction between the table and the floor are μ_s and μ_k. Neglect friction between the window frame and the rope.



a) You (mass M_P) are the first to climb out of the window. The mass of the table is insufficient to prevent it from sliding when you are suspended from the rope. We approximate the system with the schema shown in the figure (where the pulley and rope are massless). What is the maximum mass of the table?

1. Escape through a window

b) To keep from sliding, you put a vase on top of the table, whose mass is M_V. What is the minimum mass of the vase so that the table+vase do not move while you are suspended from the rope?

1. Escape through a window

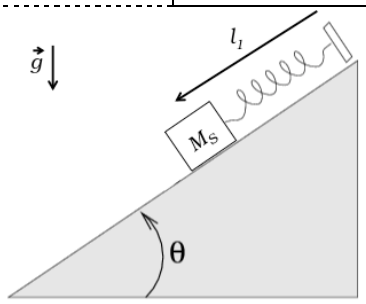
c) Your flatmate (colocataire) (mass $M_F > M_P$) climbs out after you reach the ground. The combined mass of the table and vase are insufficient to prevent them from sliding with respect to the floor. Assuming the table and vase move with the same velocity, what is their acceleration?

1. Escape through a window

d) The coefficient of static friction between the vase and the table is β_s. What is the maximum value of M_F such that the vase doesn't slide with respect to the table?

2. Oscillating sled (luge)

Some children decide it would be fun to attach a sled to a tree on a snowy hill (incline angle θ with respect to horizontal) by an elastic bungee cord. The bungee cord is approximated as a spring, with spring constant k. The sled of mass M_s is approximated as a point mass. After the sled is attached, it has an equilibrium position of l_1, as shown in the figure. Neglect friction.



a) A child of mass M_c climbs into the sled. What is the equilibrium position l_2 of the child+sled?

2. Oscillating sled (luge)

b) The sled is initially held in place at position l_1 by her friends as she climbs in, and then it is released from rest. What is the speed of the sled when it returns for the first time to position l_1? What is the maximum speed of the sled, and what is the length of the spring when it occurs?

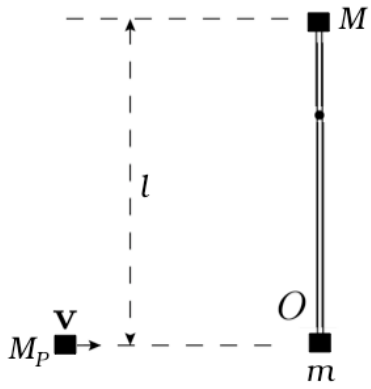
2. Oscillating sled (luge)

c) Write the equation of motion for the child+sled. What is the period ω of their oscillation?

2. Oscillating sled (luge)

d) A general solution to the equation of motion is of the form $x(t) = x_0 + A\cos(\omega t + \varphi)$. Find the particular solution, for the situation described in (b), and use it to find the speed of the sled at position l_2.

3. Horizontal collision with a barbell (haltère)
Consider a collision in the horizontal plane (xy-plane). A projectile of mass M_P collides with a barbell (a solid body composed of two point masses, M and m connected by a rigid bar of negligible mass and length l). At the moment of the collision, assume the velocity of the projectile is horizontal and of magnitude $|\vec{v}|$, as schematized in the figure. After the collision, the projectile is embedded (encastré) in the target m. Take the position O (the initial position of mass m) to be the origin of the inertial coordinate system. Neglect friction.



a) Determine the total linear momentum $\vec{p}_{tot}$ of the system (projectile+barbell) before the collision, in the reference frame where the barbell is at rest. Is the linear momentum conserved in the collision? Explain.

3. Horizontal collision with a barbell (haltère)

b) Find the position of the center of mass, l_{CM} in terms of the masses and the length l. Show that $l_{CM} \to l$ (or equivalently, $l_{CM} - l \to 0$) as $M \to \infty$.

3. Horizontal collision with a barbell (haltère)

c) Let ω be the magnitude of the angular velocity after the collision. Calculate the angular momentum of the system after the collision with respect to the center of mass, in terms of the masses, the length l, and ω. Give its direction.

3. Horizontal collision with a barbell (haltère)

d) Determine ω in terms of m, M_p, v and l. Find the limit of ω for $M_p >> m$ and $M_p << m$, and discuss each case.